OBSERVING TIME PROPOSAL FORM FOR

THEMIS - 2026

PROPOSAL

- **French time application**, email this form to: `themis.team@themis.iac.es`
Deadline: Friday February 13th, 2026

- **International time application**, email this form to: `themis.team@themis.iac.es`
Deadline: same as above

Also: ⇒ For technical details or instrumentation updates, please consult our website at:
`http://themis.iac.es` or inquire at: `themis.team@themis.iac.es`
⇒ Read the observation regulations on the last page of this form

1 General Information

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Co–Investigators(s):
[1] Etienne Pariat (PhD co-supervisor), Saida Diaz Castillo, Bernard Gelly;
[2] Sophie Masson (PhD co-supervisor), Jade Touresse, Léa D'Herbomez, Guillaume Aulanier;
[3] Gabriel Ho Hin Suen, Clara Froment, Thierry Dudok de Wit.

Affiliation(s): [1]FSLAC; [2]LPP ; [3]LPC2E

Title of Project: Magnetic field measurement of jet source regions in solar coronal holes

Specify the observation modes: **MTR2** [X] **Polar** [X] **BBI** [X] **Special** [ ]

Number of days requested: 6

[ ] **This proposal is linked to a PhD thesis preparation**
[X] **This proposal is lead by a PhD student**

2 Proposed programme

A - Scientific rationale
Concise scientific background of the project, pertinent references; previous work plus justification for present proposal.

The recent discovery of switchbacks (SBs) - localized magnetic deflections in the solar wind - by Parker Solar Probe (PSP ; Fox et al. 2016), has spurred a growing interest in understanding their origin. One prominent theory suggests their formation in the lower corona through a process of magnetic reconnection akin to solar jet formation (Bale et al. 2023). Based solely on solar observations, some studies speculate that SBs may be induced by jet-like events (Neugebauer 2012; Sterling & Moore 2020; Huang et al. 2023). However, establishing a direct association between a specific coronal jet observation and in situ measurements remains challenging, particularly in terms of magnetic connectivity (Bizien et al. 2025).

Similarly to SBs, solar jets are both intermittent and ubiquitous phenomena, prominent in the low solar atmosphere. These impulsive, collimated, and outwardly propagating transient features are observed over a broad range of spatial scales and of wavelengths (see reviews of, e.g. Raouafi et al. 2016; Shen 2021). Some large-scale jets have been observed propagating over a few solar radii away from the solar surface (Nisticò et al. 2009; Hanaoka et al. 2018). Despite their prevalence, many aspects of solar jet dynamics remains poorly constrained. To investigate the possible link between solar jets and SBs, the ANR-funded project JET2SB (Project n°ANR-25-CE31-7416), which is funding my PhD, aims at determining to which extend solar jets are projenitors of switchbacks.

Touresse et al. (2024) has recently produced innovative 3D numerical simulations of solar jet propagation based on the framework of Pariat et al. (2009). Using the ARMS 3D MHD numerical code (DeVore 1991), Touresse et al. (2024) demonstrated that the leading structure of these jets - a torsional/magnetic untwisting wave - can produce signatures similar to SBs. My PhD project, started in December 2025, aims to build on Touresse et al. (2024) in order to test different elements of the parameter space of the simulation set-up. In particular, I aimed at developing simulations that more tightly incorporate data constraints, in particular regarding the magnetic topology. Touresse et al. (2024) simulations relies on a "anemone" shape topology, characterized by a dome-shaped separatrix surface with a 3D null point, fan surface, and two spine lines (Longcope 2005). This topology aligns well with the observed characteristics of jet-like events (Schmieder et al. 2013; Joshi et al. 2020) and the "anemone" shape of the jet source source regions (e.g. Shibata et al. 1992; Moreno-Insertis et al. 2008; Liu et al. 2011; Zhang et al. 2012).

My objective is thus to be able to use magnetogram-based 3D magnetic field reconstruction (i.e. so-called magnetic extrapolation Wiegelmann et al. 2017) as initial conditions for my simulations. Since the seminal study of Masson et al. (2009), magnetic-extrapolation-initiated simulations are becoming more and more common (Guo et al. 2024), in particular for (erupting) active regions. To the best of my knowledge, none of these data-initiate simulation has focused on the case of coronal jets. This is likely the outcome of the smaller spatial scale than active regions of jet source regions: space magnetic field measurements are likely not sufficiently

resolving the source region with insufficient spectropolarimetric sensitivity. It is thus fundamental to benefit from high-resolution and high-polarimetric sensitivity observations such as the ones provided by THEMIS/MTR for this scientific objective.

My innovative data-initiated simulations shall provide more realistic dynamics of the trigger and onset of coronal jets. They shall lead to a better understanding of the physics of their propagation, hence addressing the key questions of the JET2SB project:

- Do, and to which extend, solar jet-like events induce Switchbacks (SBs)?
- Which families/properties of solar jets can explain the different signatures of SBs?
- What are the physical mechanisms involved in the jet propagation and SB formation?
- Do these mechanisms lead to energy deposition contributing to the acceleration of the solar wind?

B - Immediate objectives

Immediate objective of the proposal: state what is actually going to be observed, what shall be extracted from the observations, so that the feasibility becomes clear.

THEMIS observations carried in this proposal aims at producing high-resolution vector magnetic field maps in order to have the necessary element for the production of coronal magnetic extrapolation.

The objectives of the proposal is to obtain regular Stokes data cube of jet source regions, in particular those that could induce switchbacks. As regions of open magnetic fields connected to the fast solar wind (e.g. Kumar et al. 2022; Skirvin et al. 2023), coronal holes are ideal sites for studying jet-like events as precursors of SBs.

The measurement of the photospheric vector magnetic field, with a full polarization sequence, is essential for latter being able to reconstruct the 3D coronal magnetic field and determine the topology of the jet source regions. We have selected to use the magnetic sensitive Fe I doublet @6302 Å, as our main lines to obtain the Stokes parameter. The choice of the Fe I doublet @6302 Å is driven by the slight different g-factor in each line, which allows to constrain better the magnetic field and line-of-sight velocity during the magnetic inversion.

A secondary requirement is to obtain simultaneously chromospheric observations. Jet source region are basically not apparent in photospheric lines, as such region are too small and with too weak magnetic field to initiate the formation of pores, and can thus only be spotted thanks to their chromospheric emission. We are thus interested in analysing the H_α (@ 6563 Å) and Ca II (@ 8542 Å) lines. They will serve me mainly to identify the target of interest.

In a secondary manner, I will also use them to follow the dynamics of the jet region. Emission in chromopsheric line center will inform us on possible heating because of activity and we shall be able to relate this with the evolution of the magnetic configuration. My observation could also be combined with EUV observation from SDO/AIA, Solar Orbiter/EUI and/or IRIS, if available, to obtain the coronal response of the 3D null dynamics.

Additionally, the Ca II line is magnetically sensitive and its analyse with polarimetry can eventually provide us with chromospheric magnetic fields. Ca II chromospheric magnetic field

measurements are however yet not fully mature (Felipe et al. 2021), and these magnetic field estimation are only a tertiary objective.

C - Strategy for observing

Brief description of the observation method

The 2025 campaign of Etienne Pariat and Jade Touresse, co-investigator of this proposal, has enabled them to optimize the observation strategy of jet source region, which nourishes the present observation strategy.

Because I intend to perform magnetic field measurement, it is important that targets are as close as possible to solar disc-center to minimize projection effect and impact on the magnetic measurements. I will thus primarily target low-latitude extension or polar coronal holes and/or equatorial coronal holes. Such low-latitude extensions/equatorial coronal holes are common around solar maximum, hence this proposal is timely.

If such coronal hole is present, in the first hour of the day, when the seeing is still poor, I'll perform fast scans (90" scanning range at 0.6" steps, without polarisation) of neighboring regions within the target coronal hole. Thanks to preliminary analysis of quicklooks of the data, this will enable me to determine a target/region of interest (roi): a well visible anemone region, hopefully already displaying sign of jetting activity. I'll also use readily available space surveillance data (e.g. from SDO) to help me in election the target.

Once the roi has been selected, the objective is to follow this region for the rest of the day, while seeing conditions permits. As my focus is on magnetic field measurement, I'll carry scans of the roi, with a 0.3" step, with full polarimetry (+V,-V,+U,-U,+Q,-Q). These scans shall last about 30 min. The scans shall permit to obtain vector magnetograms and the best magnetic reconstruction possible.

In case of absence of equatorial coronal hole, one could target polar coronal holes, although the high inclination regarding to the line-of-sight implies less meaningful magnetic field measurements. Other possible secondary targets are 3D null that forms in the vicinity of active region. Because of the more complex magnetic environment, understanding their dynamics is however less obvious that in equatorial coronal holes.

D - Strategy for data reduction and analysis

Brief explanation of the strategy for data reduction and analysis with description of available hardware, software, expected publication

Preliminary onsite data analysis, in order to check whether the target are indeed interesting, will be done with the tools present at THEMIS. Further analysis, magnetic inversion will be carried using V. Bommier magnetic field software, as well as magnetic inversion codes from colleagues from the IAC.

The vector magnetograms will then be used as inputs for magnetic extrapolations. Our team has collaborated with a vast range of international colleagues who have used different types of extrapolation methods and assumptions, e.g. linear force free (e.g. Gary 1989), non-linear force free (e.g. Valori et al. 2005; Wiegelmann et al. 2012), non force free (e.g. Hu et al. 2010; Guo et al. 2024).

E - Conditions necessary to reach the scientific objectives
Specify the critical need of: clear days, good seeing, level of solar activity...

Given that we are now in the early decreasing phase of the solar cycle, the level of solar activity remains high and equatorial coronal holes, and or low latitude extension of polar coronal hole shall be present.

Jet source/anemone regions being relatively small sized, good to excellent seeing conditions are necessary. In case of poor seeing, we shall likely change of target and science program in order to focus on larger scale activity, e.g. active region flares.

F - Minimum observation time necessary to reach the scientific objectives
Assuming good weather

The minimum observing time is about 3 days in order to capture several regions and possibly follow them over a few days, which corresponds to their typical lifetime.

G - Report on the use of THEMIS over the last 3 years
If you have been using THEMIS during the last 3 years, describe(briefly) the quality/value of the data obtained and the scientific output generated.

N/A: I have never used THEMIS before

3 Scheduling and support

A - Coordinated observation:
Please indicate if you are planning coordinated observations with other facilities.

No coordinated observations are scheduled at the moment. Some coordinated observation may be put in place at a latter time, but they shall no induce constraints on the actual planning.

B - Impossible Dates:

The PhD defense of Jade Touresse, at a date not known yet, shall take place in September 2026, will constitute a strong availability limitation. The defense date shall however hopefully be known in the coming weeks.

C - Skills and support

[ ] I am expert in telescope and instrument handling and need no assistance.
[ ] A little help will be fine.
[X] I am not familiar with the telescope and/or the instrument and need assistance.

4 Technical proposal / Instrumental configuration

For the 2026 campaign, THEMIS proposes nominally:

1. **MTR2 in spectroscopy mode**
   In this mode we propose up to 4 (old) EMCCD Andor iXon camera (512x512) and up to 2 (new) Andor Zyla (2kx2k) cameras. Both 6 cameras can be setup and used at the same time (with their respective specs), in accordance with the SP2 output physical limitations.
2. **MTR2 in spectropolarimetry mode**
   THEMIS polarimetric analysis scheme is based on a full-Stokes analyzer located at the F1 prime focus. For any solar polarization state to measure, the output of the analyzer is made of dual superimposed complementary linear polarizations. Thanks to THEMIS polarization friendly new optical scheme, this output travels through the telescope and arrives unperturbed on the spectrograph cameras. Just in front of the camera, a Wollaston splitter separates the beam into complementary Stokes components to form the spectral focal plane.
   THEMIS owns three Wollastons, hence 3 cameras/3 wavebands at most can be simultaneously observed with polarimetric signal, among the 6 spectral cameras that THEMIS proposes. It is however possible to combine polarimetric and non-polarimetric cameras.
3. **Broadband imaging camera, running concurrently with the spectrograph** Nominal setup is for G-band, but this can be changed optionally (current setup is for 650 nm (red))
4. **THEMIS Adaptive optics (TAO)** is available and tested over sunspots and granulation with good results over significantly long periods of time (seeing dependent).

   - A slowed-down (100Hz) version of the same system can be used to stabilize Mercury.

   - While it is not possible to use TAO directly over the solar limb (or for neighboring prominences), during the 2025 campaign, tests have been carried to observe prominences while TAO was focused on granulation over an offset on-disc region. Even though the TAO isoplanatic region was located far from the targeted prominence, TAO nonetheless provided noticeable improvements.
5. **Available analysis softwares**

   - Knox Thompson image reconstruction for BBI

   - Reconstructed spectral map quick-looks for on site analysis, to be adapted to specific wavelength.

   - Stokes map quick-looks

   - Thanks to V. Bommier, a basic magnetic field inversion software package (running locally in IDL) is also available.

Please indicate below your expected technical setup. Remember that a spectrograph simulator and an acquisition simulator are available at `https://themis.iac.es/doku.php?id=technical:mtr2`
As a minimum, indicate the spectral wavelengths at which you will be using the MTR spectrograph and the need for spectropolarimetry.

We would like to use the TAO capacities and our project requires polarimetric measurements.

Similarly to the proposal of E. Pariat, I would like to use MTR2 with the following lines with polarimetric measurements/cameras:

- Fe I doublet @ 6302 Å, with Zyla Camera
- Ca II @ 8542 Å, with Andor Camera.

and the following one without need of polarimetry:

- H_α @ 6563 Å, with Zyla Camera

The spectral simulators has indicated that this set up is do-able.

Simultaneously to MTR2 observations, I shall also use the BBI camera for context images of the target.

References

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Observer Charter at THEMIS

All data obtained at THEMIS remain the property of CNRS[1]. No observing fee is requested from observers. Observers are requested to collaborate with THEMIS regarding the data formatting, and to provide information about observing conditions and all information needed concerning the data processing.
The observer agrees to :

- **acknowledge the use of the THEMIS telescope in any published paper using the corresponding data.**[2]

[1] Centre National de la Recherche Scientifique, 3 rue Michel-Ange, F75794 PARIS Cedex 16, FRANCE

[2] "The THEMIS telescope is operated on the island of Tenerife and yearly funded by the french Centre National de la Recherche Scientifique - Institut National des Sciences de l'Univers: CNRS-INSU"